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Measurement of Natural Radioactivity Concentrations in Different Brands of Incense in Iraq

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Abstract

This study was carried out to evaluate the activity concentration of natural radioisotopes that exist in different incense (bakhour) samples collected randomly from the local markets in Baghdad, Iraq. Very few data have been published that focused on the concentrations of natural radionuclides in incense. The analysis was done using a high-purity germanium detector. The results indicate the existence of a wide range of radioactivity contents among the different tested products as follows; 9.5 to 53.1 Bq.kg^{-1} for the ^{226}Ra, 3.5 to 21.2 Bq.kg^{-1} for ^{232}Th and 332 to 1717 Bq.kg^{-1} for ^{40}K. The mean radioactivity concentrations for the nine samples were 26.5, 10.4, and 794 Bq.kg^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K respectively. Prediction of the annual intake of incense for a single consumer was difficult to achieve, therefore two scenarios were considered and the findings concluded that incense smoke is safe from a radiological exposure perspective for the presence of the investigated radionuclides.

Keywords: Incense; Natural Radioactivity; Inhalation; Gamma Spectroscopy; HPGE

1. Introduction

Incense burning is a traditional, religion and common practice in many families in Iraq, the Middle East, south of Asia, and in many cultures. Incense has been used for centuries for ceremonial purposes, fragrancing the environment in temples, mosques, churches, and residential houses, representing one of the most significant sources of combustion-derived particulate matter in indoor air. Incense comes in many different compositions and forms chemically and physically. The chemical composition of incense can vary depending on the specific type of incense, its ingredients, and the manufacturing process. For example, a typical stick incense consists of 21% of herbal and wood powder, 33% of bamboo stick, 35% of fragrance material, and 11% of adhesive

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powder [1,2]. However, several common components are often found in incense smoke. Here we list some of the main components:

- Volatile Organic Compounds are organic chemicals that can easily evaporate into the air. Examples include benzene, toluene, xylene, and formaldehyde. The presence of these compounds is associated with the burning of plant materials and additives.
- Particulate Matter including fine particles and coarse particles. These particles may contain various substances, including organic compounds, metals, and ash.

  Lofroth et al. [3] studied two types of incense and found that 51–54 mg of particulate matter was in one gram of incense burned compared to 24–37 mg/g for cigarettes. On average, incense burning produces particulates greater than 45 mg/g burned as compared to 10 mg/g burned for cigarettes [1].
- Polycyclic Aromatic Hydrocarbons which are organic compounds that can form during the incomplete combustion of organic materials are already known as carcinogens [4,5].
- Aldehydes and Ketones are compounds that contribute to the distinctive smell of incense but may also have health implications.
- Heavy Metals such as lead, cadmium, and mercury, which can be released into the air during burning [6].
- Aromatic Compounds: Many types of incense contain aromatic compounds derived from natural resins, gums, and essential oils. These compounds contribute to the fragrance of the incense. Common sources include frankincense, myrrh, sandalwood, and various plant extracts [1].
- Gas products from incense burning include CO_2, CO, SO_2, NO_2, and others [5].

Incense, regardless of its type, is ultimately the product of the combustion of hundreds of compounds that we inhale from incense. Incense smoke may trigger asthma attacks or severe chest allergies and some cases of lung fibrosis particularly in poorly ventilated indoor environments. Indeed, studies have correlated incense use with upper respiratory tract cancer [7] and asthma attacks [8,9]**.** Individuals with respiratory conditions or sensitivities may be more susceptible to the potential adverse effects of incense smoke, other studies on the chemical toxicity [5] and physical characteristics [10].

Smokes and fumes produced from burning any raw material may contain minute amounts of radiotoxic elements such as ^{210}Pb, ^{210}Po, and ^{238}U which are inhaled and settle in the lungs. In the opposite of cigarettes and Shisha, the radioactivity presence in Incense has not been studied enough. Elsayed et al. [11] compared the concentration of Lead in cigarette tobacco and backhor samples chemically and the author found that the concentration in tobacco was in the range of 0.6-2.4 mg/kg while in backhor the lead concentration was much higher, between 2.03-3.24 mg/kg. Alrefae [12] studied 27 samples of incense brands (natural and processed) collected from the Kuwaiti local markets and compared their results with cigarettes and Moassel. Alrefae [12] showed that the activity concentration of naturally occurring radioactive materials (NORM) of ^{226}Ra in processed incense was 25.5 $Bq.kg^{-1}$ which is about nine times the activity in cigarette and Moassel (3 $Bq.kg^{-1}$). On the other hand, ^{40}K was in the same range as the cigarette (600 to 900 $Bq.kg^{-1}$).

In Iraq, incense is used intensively in festivals, shrines, and cemeteries, as a ritual, meditation, and relaxing habit, and the incense shops to attract customers. Elsayed et al. [11], Alrefae [12], and other studies showed that the presence of heavy elements, especially Lead with high concentration relative to tobacco, these studies motivated us to study and quantify the NORM in incense and to estimate the dose caused by incense smoke which is the objective of this study.

2. Material and Methods

Incense samples were collected randomly from local markets in Baghdad The collection took place between April and May 2023. To ensure a comprehensive and widespread representation, nine different samples that originated from seven different countries were selected (Table 1). The cost of the products was relatively low and affordable, especially for low-income people who by the way use incense the most (Fig. 1).

Table 1: The name, code, origin country other details of the incense samples

Sample code	Brand name	Country of Origin	Physical form	Density in $g.cm^{-3}$
S1	Reema	India	Chunks	0.39
S2	Dar Eloud	UAE	Chunks	0.39
S3	Qayser Araaysi	Iraq	Chunks	0.20
S4	Rymthm	India	Sticks	0.41

S5	Oud Salala	Oman	Chunks	0.36
S6	Mitromilan	Pakistan	Sticks	0.54
S7	Al-Amira	UAE	Chunks	0.42
S8	Shiekh-Zayid	UAE	Chunks	0.49
S9	Zahra	KSA	Chunks	0.36

Figure 1: A photograph of the incense products used in this study (on the left), one of the samples after preparation and stored in the test container (on the right).

The samples were dried for two days in the bright sunlight, and then crushed and pulverized by a mortar and pestle since it was difficult to use an electric grinder due to the stickiness and gumminess of some samples as mentioned in the introduction incense has chemical binders in its composition. The samples were then ground and homogenized. The sample dry mass was measured and packed in an airtight cylindrical polyethylene plastic container and pressed firmly to remove any air pockets. The sample containers were stored for about four weeks before the analysis to achieve secular equilibrium between ^{226}Ra and its daughters before being taken for gamma spectrometric analysis.

Measurements were performed using a high-purity germanium (HPGe) detector FALCON5000 (Canberra) in the Department of Measurements and Calibration, Iraqi Radioactive Sources Regulatory Authority (IRSRA). The detector used in this study has a relative efficiency of 40% and full width at half maximum of 2 keV for a ^{60}Co gamma energy line at 1332 keV. The Energy calibration for the detector was performed using two point sources: ^{137}Cs and ^{60}Co. The detector was shielded by 10 cm thick lead bricks adequate to reduce the background radiation. An empty container was used to collect the background spectrum under the same conditions and the same acquisition time which is three hours (10,800 sec), this background spectrum was subtracted from the spectrum collected from the samples to get the net number of counts.

The Efficiency calibration was done using the LABSOCS software developed by MIRION technologies which is based on the Monte-Carlo technique for each energy peak and the efficiency was in the range of 0.0648 to 0.0127 as shown in Table 2. For spectrum analysis, the Genie2000 software tool was used for both the spectrum acquisition and the analysis using the analysis sequence recommended by the manufacturer.

Table 2: The key gamma peak energies of the detected radioisotopes and the related calculated efficiencies.

Radioisotope	**Energy peak in keV**	**Gamma peak intensity %**	**Efficiency**
^{40}K	1460.81	10.67	0.0127
^{212}Bi	727.17	11.80	0.0235
^{212}Pb	238.63	44.60	0.0648
^{214}Bi	609.31	46.30	0.0275
	768.36	5.04	0.0224
	934.06	3.21	0.0189
	1120.29	15.10	0.0161
^{214}Pb	241.98	7.49	0.064
	295.21	19.20	0.0529

3. Results and Discussion

The activity concentration of the radionuclides detected in the samples is calculated implicitly by the Genie2000 based on equation (1). All the radionuclides detected and quantified came from the naturally occurring ^{226}Ra and ^{232}Th decay series as well as non-series ^{40}K.

$$A_c = \frac{C_{net}}{Eff \ I_\gamma \ t \ m} \qquad (1)$$

Where $C_{net}$the net area under peak (counts), t is acquisition time (sec), I_γ is the gamma yield probability (all the gamma energy probabilities are listed in Table 2), Eff is detector efficiency for the corresponding gamma peak and m is the mass of the sample in grams. The efficiency calibration depends on detector properties, sample (container) geometry, sample material and other factors LABSOCS a software developed by MIRION uses Monte-Carlo techniques to generate efficiency points for each value of energy along the spectrum.

In Figure 2, it can be noticed that the results of the analysis showed that the highest activity concentration was found to be in sample 3 which belongs to the Iraqi product "Qayser Araaysi" with 53.1±8.5 Bq.kg^{-1} for the ^{226}Ra, 21.2 ±4.7 Bq.kg^{-1} for ^{232}Th and 1717±100 Bq.kg^{-1} for ^{40}K. In contrast, the lowest activity concentration was in sample 7 which is the "Al-Amira" product from UAE with 9.5±1 Bq.kg^{-1} for the ^{226}Ra, 3.5 ±1 Bq.kg^{-1} for ^{232}Th and 331.6±18 Bq.kg^{-1} for ^{40}K. The mean radioactivity concentration for the nine samples was as follows; 26.5, 10.4, and 794 Bq.kg^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K respectively.

Additionally, the mean activity concentration as presented in Table 3, and found to be in matching with the results of Alrefae [12]. Also, Table 1 provides a comparison between different materials that produce smoke and it is clear that Incense is more radioactive than cigarettes, Tobacco, and charcoal.

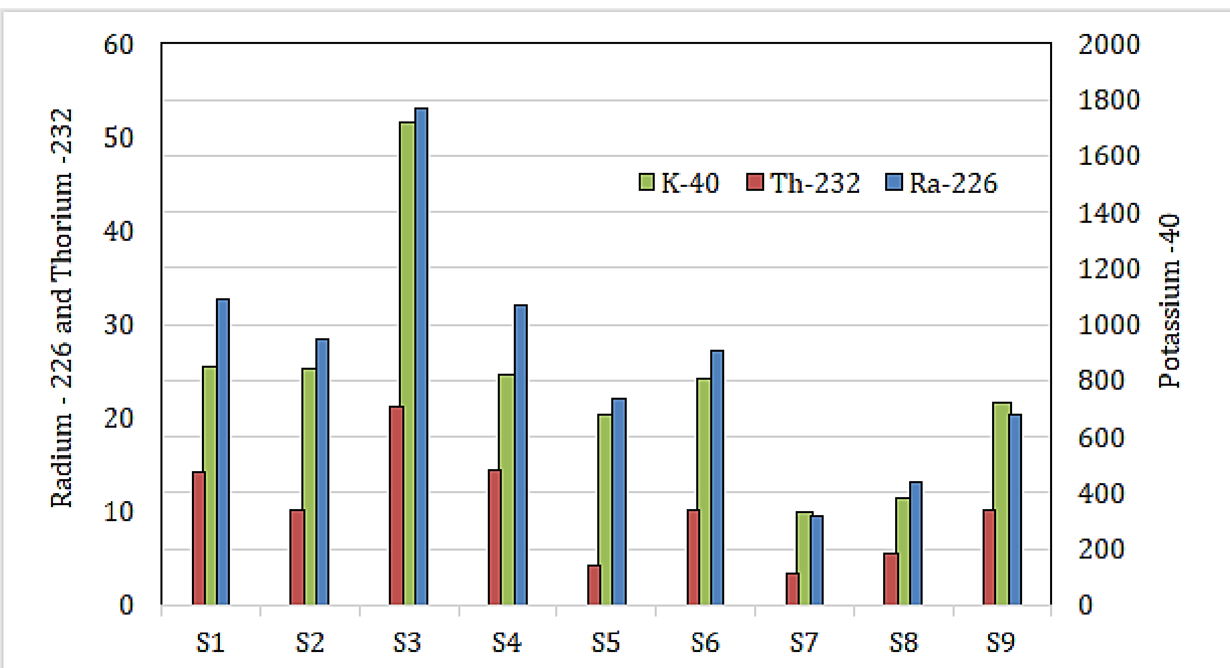

Figure 2: The activity concentration of ^{226}Ra, ^{232}Th ^{40}K in Bq.kg^{-1}

Table 3: a comparison between the average activity concentration in incense and other smoke-production materials

Study	**Material**	**The average activity concentration of natural radionuclide in Bq.kg^{-1}**		
		^{226}Ra	**^{232}Th**	**^{40}K**
Present study	Incense	26.5	10.4	794
Alrefae [12]	Incense	25.5	18.7	640
Hussien [13]	Harmal seeds	-	-	425
Ridha and Hasan [14]	tobacco	14.86	10.84	1050.64
Baiwa and Koki [15]	cigarette	14.38	7.40	567.60
Abdul-Majid et al. [16]	charcoal	3	2	163

The concentration and distribution of ^{40}K, ^{226}Ra, and ^{232}Th in soil are not consistently distributed over the globe. The Radium equivalent activity (Raeq) is used as a standard indicator to represent radiation risk. The Raeq index is a commonly used radiological hazard index. It was defined based on the assumption, that 1 Bq.kg^{-1} of ^{226}Ra, 0.7 Bq.kg^{-1} of ^{232}Th, and 13 Bq.kg^{-1} of ^{40}K produce the same gamma dose rate. It was calculated as follows,

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \qquad (2)$$

Where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq.kg^{-1}, respectively [17]. The radium equivalent activity index values, Raeq (Bq.kg^{-1}) for incense samples ranged between ٨٠.2 and 215.6 Bq.kg^{-1} (see Fig. 3) with an average of 127.3 Bq.kg^{-1}. These values were found to be lower than the recommended limit of 370 Bq.kg^{-1} [18], and hence do not pose a noticeable health risk.

Another widely used factor to assess the dose rate from gamma radiation in the air at 1 meter from the surface of a pile of the sample:

$$D = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K \qquad (3)$$

Where, A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq.kg^{-1}, respectively. The values ranged between ٤١,١ to ١٠٩,٢ nGy h^{-1} (see Fig. 3) with an average of ٦٤,١ nGy h^{-1} All the calculated values of the absorbed dose rate for the incense samples were high when compared to the recommended limit of 57 nGy.h^{-1} (UNSCEAR 2000), however, about 70% of the Charcoal samples were higher.

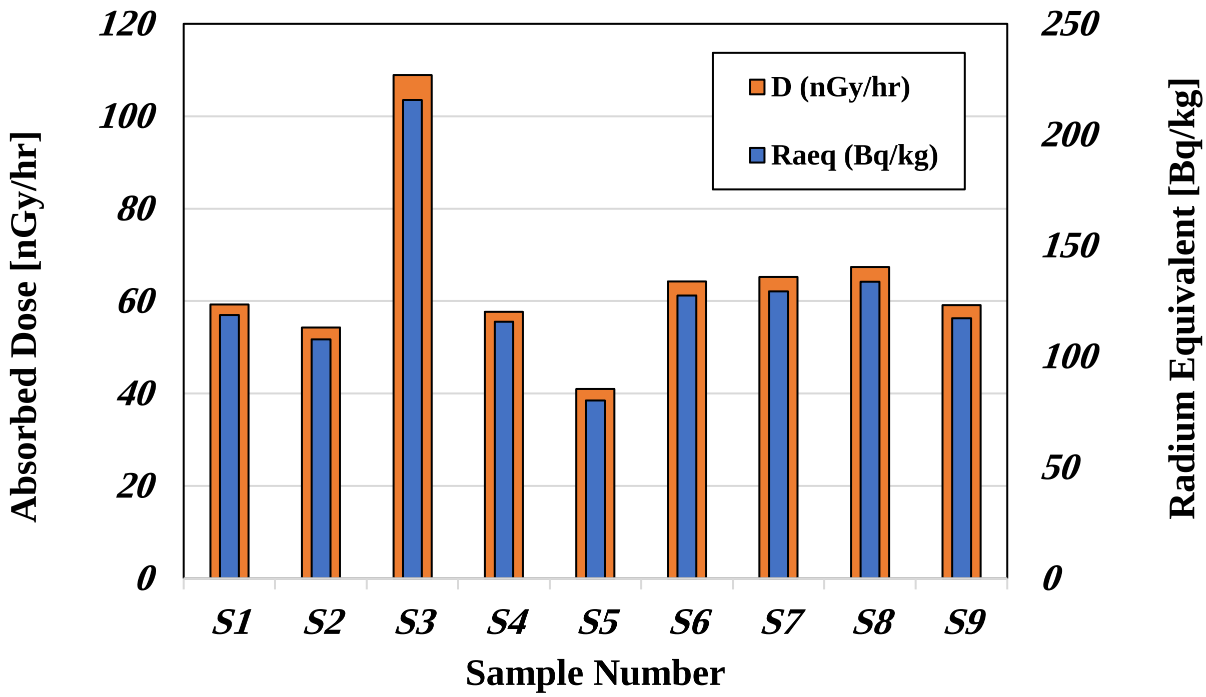

Figure 3: Radium equivalent in Bq.kg^{-1} and absorbed dose in nGy.hr^{-1} for the studied incense samples.

The annual effective dose from inhalation of incense smoke can be estimated using the formula [18]:

$$AED = A\ E\ I \qquad (4)$$

Where AED is the annual effective dose (Sv.yr^{-1}), A is the activity concentration for the radionuclide (Bq.kg^{-1}), E is the dose conversion factor for the radionuclide (Sv.Bq^{-1}) which is listed in Table 4, and I is the annual intake of incense (kg.yr^{-1}).

Table 4: Effective dose conversion factors for inhalation for adults [19].

Radionuclide	**Sv.Bq^{-1}**
^{212}Pb	$1.8x10^{-8}$
^{212}Bi	$9.1x10^{-9}$
^{214}Pb	$2.8x10^{-9}$
^{214}Bi	$7.1x10^{-9}$
^{40}K	$2.1x10^{-9}$

The main obstacle against calculating the AED is the annual intake of incense (kg.yr^{-1}). To obtain accurate and specific information on the annual usage of incense in a particular region or community, it would be necessary to refer to local surveys, market research data, or relevant cultural and religious studies that provide insights into incense consumption patterns. Additionally, data from incense manufacturers or retailers may offer information on sales and consumption trends in specific markets.

For simplification, we will consider a scenario that is based on burning a single stick of incense per week (48 times per year). Four incense sticks were weighed before and after burning (the ash) and turned out that the burned mass was 0.8 -1.1 g. Hence, the amount of incense that is burnt is around 50 g.yr^{-1} which is quite a reasonable intake while Lin [1] stated that the annual consumption of incense in Taiwan is 156 g.yr^{-1}. We will assume 1% of the annual burned mass of the incense is inhaled, Therefore the results of the annual effective dose calculation based on the above assumption are presented in Table 5.

Table 5: Annual effective dose from burning one stick weekly in nSv.yr^{-1} according to two assumptions of annual consumption

Sample	**0.5 g. yr^{-1} (present study assumption)**	**156 g. yr^{-1} (Alrefae [12] assumption)**
S1	1.34	419.14
S2	1.25	388.36
S3	2.275	709.89
S4	1.16	362.22

S5	0.87	272.59
S6	1.11	346.02
S7	0.44	136.61
S8	0.55	171.19
S9	1.037	323.54
Mean	**1.15**	**348**

Considering the above scenario, the results showed that the dose from inhalation of 1% of the smoke of the burnt incense causes is very low. Calculations were also done based on Alrefae's [12] assumption which considers that the annual amount that is inhaled is 0.156 $kg.yr^{-1}$, the mean AED found to be 1.15 $nSv.yr^{-1}$ for our scenario while the mean AED would be 348 $nSv.yr^{-1}$ if we assume a person inhaled 156g of incense material per year. In both cases, the dose is still low compared with other sources of radiation.

In light of these findings, it is concluded that incense smoke is safe from a radiological exposure perspective for the presence of the investigated radionuclides.

4. Conclusions

There are very limited publications on natural radionuclide concentration in incense products. This study aimed to shed more light on the activity concentration of natural radionuclides in incense that is used for many purposes. The results of our study indicate the existence of high values of radioactivity contents in incense compared to tobacco. However, fortunately, the amount of inhaled smoke is much less. We recommend the need for more research on the radioactivity in incense, the annual consumption surveys, their behavior during smoking, and the effect of different parameters. Public health priority should be essential to develop countermeasures for the prohibition of all forms of smoke products (cigarettes, narghiles, and maybe incense) wherever and whenever possible in indoor areas.

5. Acknowledgment

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6. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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الملخص العربي

قياس تراكيز النشاط الإشعاعي الطبيعي في ماركات مختلفة من البخور في العراق

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<u>الملخص العربي :</u>

أجريت هذه الدراسة لتقييم تركيز نشاط النظائر المشعة الطبيعية الموجودة في عينات مختلفة من البخور تم جمعها عشوائيا من الأسواق المحلية في بغداد، العراق. وقد تم نشر القليل جدا من البيانات حول تركيزات النويدات المشعة الطبيعية في البخور. تم إجراء التحليل باستخدام كاشف الجرمانيوم عالي النقاء. تشير النتائج إلى وجود مجموعة واسعة من محتويات النشاط الإشعاعي بين المنتجات المختلفة المختبرة على النحو التالي؛ ٩,٥ إلى ٥٣,١ بيكريل/كجم لـ ^{٢٢٦}Ra، ٣,٥ إلى ٢١,٢ بيكريل/كجم لـ ^{٢٣٢}Th و ٣٣٢ إلى ١٧١٧ بيكريل/كجم لـ ^{٤٠}K. كان متوسط تركيزات النشاط الإشعاعي للعينات التسع ٢٦,٥ و ١٠,٤ و ٧٩٤ بيكريل/كجم لـ ^{٢٢٦}Ra و ^{٢٣٢}Th و ^{٤٠}K على التوالي. كان من الصعب التنبؤ بالاستهلاك السنوي للبخور بالنسبة لمستهلك واحد، لذلك تم النظر في سيناريوهين وخلصت النتائج إلى أن دخان البخور آمن من منظور التعرض الإشعاعي لوجود النويدات المشعة التي تم التحقيق فيها.